Continental-Margin Processes Recorded in Shelf and Canyon Sediments Documenting Fine-Sediment Import and Export for Two Contrasting Mesotidal Flats

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LONG-TERM GOALS

The ultimate goal of the work in the Gulf of Lions was to understand the relationships between sediment transport and accumulation in shelf and slope environments, and how they lead to the formation and preservation of sedimentary strata in the seabed.

The goal of the tidal-flats project during the past year was to initiate pilot studies in tidal mud flats (Willapa Bay) and sand flats (Skagit Bay).

OBJECTIVES

The objectives of research during FY08 were to:

1) submit and publish papers about: Rhone flood deposits; off-shelf transport into Cap Creus and Lacaze-Duthiers canyons; and an integrated evaluation of the Gulf of Lions sediment dispersal system;
2) collect samples and data regarding sedimentation in Willapa and Skagit Bays, and use these to collaboratively design more complex field/lab studies for FY09;
3) provide logistical support for the community of ONR-funded scientists working in Willapa and Skagit Bays.

APPROACH

The research completed in the Gulf of Lions will be disseminated through three primary papers published in international journals (Continental Shelf Research, Marine Geology, Journal of Sedimentary Research). In addition, collaborative studies with other investigators also will be published. See Publications.

The tidal-flat sedimentation in Willapa mud flats and Skagit sand flats will be contrasted, with a focus on understanding the import of mud to the Willapa flats and the export of mud from the Skagit flats. This involves development of sediment budgets to quantitatively document the fate of muddy sediment, and also includes investigation about the variability for sedimentation of several time scales: tidal, seasonal, decadal.

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Because UW is located near the Willapa and Skagit tidal flats, we are helping to provide logistical support to colleagues traveling long distances to work in these areas. We have also helped obtain the substantial number of permissions needed for the research, and have acted as the primary contact for the federal, state and county regulatory agencies.

WORK COMPLETED

Of the three primary papers from the Gulf of Lions, one has been published, another is being reviewed, and the third is about to be submitted. The collaborative papers are in various stages toward publication.

Field work has been limited by the permitting process for the two study areas. However, since approvals have been received in August and September, two four-day studies have been completed in Skagit Bay (one intertidal by small boats, and the other subtidal on the R/V Barnes) and one five-day study has been completed in Willapa Bay (by small boats).

Several months of effort were spent helping ONR obtain the necessary permits to work in the two study areas. Two boats/motors/trailers and two kayaks were purchased and outfitted for community use. A mobile observatory has been designed and built for use of heavy equipment in very shallow water (<0.5 m), which is especially important for studies on mud flats.

RESULTS

1) RHONE DELTA – Episodic flood delivery provides the bulk of the solid discharge for many small to moderate river systems, including the Rhône River in the northwestern Mediterranean. Several recent studies have demonstrated that the fate of this sediment depends on the coherence between river discharge and energetic ocean conditions. The deposition of flood sediment in the ocean can be confirmed by common signatures of episodic discharge events: presence of ^{7}Be, physical stratification, and elevated clay content associated with low ^{210}Pb activities.

Previous research has indicated that the Rhône River discharge is episodic and generally independent of oceanic conditions. Sometimes the floods coincide with energetic storms and winds from the southeast, which facilitate the movement of sediment towards the southwestern Gulf of Lions. High-resolution coring near the mouth of the Rhône River provides a detailed record of sedimentation associated with past flood events. Cores were collected on two cruises, October 2004 and April 2005, in a study area seaward of the Rhône subaerial delta. Episodic sediment discharge from the Rhône River routinely deposits on the seabed in water depths shallower than 40 m. This is documented by the presence of ^{7}Be in the surficial sediments of physically stratified cores. Through identification of a dilution signature in ^{210}Pb profiles (i.e., increased clay content, decreased ^{210}Pb activity), past flood events are recognized. Greater water depths and distances from the river mouth allow bioturbation to erase these signatures, except in the most extreme events where physical stratification is preserved. Excess ^{210}Pb and ^{137}Cs were ubiquitous in cores from this study, indicating apparent accumulation rates in the range of 2.5 to >10 cm/y. This study confirms that although flood-event signatures provide a basis with which to examine recent flood deposits of all scales, only the thickest deposits are likely to be preserved over the long term (>100 y).

2) OFF-SHELF TRANSPORT – Sediment-transport processes were examined on the southwestern Gulf of Lions continental shelf from September 2004 through April 2005. Bottom-boundary-layer

instrumentation was deployed in 86-m water depth on the outer edge of the mid-shelf mud belt to infer the mechanisms responsible for sediment resuspension, transport and off-shelf export. This study period was dominated by the formation of cold, dense-water on the southwestern Gulf of Lions continental shelf as a result of sustained winds from the north and northwest. There were no major floods of the surrounding rivers or extreme southeast storm events (resulting in large wave events). Currents on the middle shelf during the latter half of the deployment period were twice as strong as those in the initial stratified period. Suspended-sediment concentrations were moderate throughout the deployment (5-40 mg/l), with events occurring more frequently during the dense-water period (>1 g/l). Sediment resuspension by the movement of dense-water on the continental shelf likely accounts for the increase in suspended-sediment concentration at the mid-shelf tripod site. Advection of sediment from the inner-shelf and the mid-shelf mud belt to the north of the tripod site occurred with the dominant along-shore circulation. Localized resuspension at the mid-shelf tripod site was seen with the winnowing of fine-sediments in the dense-water period. Sediments in suspension are exported off-shelf towards Cap Creus and Lacaze-Duthiers Canyons via the dense-water flow.

3) GULF OF LIONS SEDIMENT DISPERSAL SYSTEM – Linkages between sediment source, transport pathway and off-shelf export mechanisms are the foundation for understanding and interpreting sedimentary processes and seabed stratigraphy. To investigate the relationship between sediment supply and margin geometry, cores (box and kasten) were collected in the various environments of the Gulf of Lions dispersal system from the Rhône prodelta region in the northeast to the bottom of the southwest canyons (Lacaze-Duthiers and Cap de Creus), on three cruises from September 2004 to May 2005. Sedimentary analyses examined spatial and temporal patterns, and included grain size, geochronology (^{7}Be, ^{210}Pb) and x-radiography (sedimentary structures). During the same time period, two bottom-boundary-layer tripods were deployed to examine sediment transport processes on the shelf and off-shelf export, one on the southwest shelf in 86-m water depth and the other in the head of Lacaze-Duthiers canyon in 186-m water depth. Sediment transport processes on the continental margin are controlled by distance from the Rhône River sediment source, morphology, and the general circulation on the continental shelf. The interaction between strong marine storms and dense-water formation control off-shelf sediment export in the Gulf of Lions. High inter-annual variability of these processes and the complex bathymetry over which they occur shape the GOL continental margin. Regional cyclonic circulation and the narrowing of the shelf in the southwest lead to shelf sediment export via the southwest canyons, Lacaze-Duthiers and Cap Creus. Sediment effectively bypasses the canyon heads due to intense current interaction and the frequent occurrence of dense-water cascading. Sedimentation in the canyon heads is asymmetrical with erosion (and coarse sediment) dominating the western flank and main entrant, and pockets of fine-grained sediment on the eastern flank where the Northern Current drapes over the canyon edge.

TIDAL-FLATS RESULTS – Samples and data have just reached our laboratories, and we have no results to report – but will do so at the workshop during December in San Francisco.

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IMPACT/APPLICATIONS

The research completed in this project leads to an improved understanding of the processes that control the geometry of sedimentary deposits over multiple time scales and in diverse oceanographic settings. Especially important is documentation for the distribution of the Rhone flood deposit, and evaluation of the seabed impact from cold-water currents cascading down the submarine canyons. The tidal-flat studies will provide an understanding of rate and type of sediment (mud, sand) emplaced on tidal flats,

which are critical for understanding the surface morphology (e.g., channel configuration) and internal character (e.g., sediment stratification that affects strength).

TRANSITIONS

Other investigators in EuroSTRATAFORM and the Tidal Flats DRI are using results from this effort. Those studying the seabed incorporate radiochemical and textural data to document seabed characteristics more fully. Researchers analyzing boundary-layer processes also utilize these data to describe instrumentation sites. Accumulation rates, sediment budgets, and grain-size data are key components to the input parameters of numerical models.

RELATED PROJECTS

Related projects include studies of: the seabed by R. Wheatcroft and P. Wiberg; boundary-layer processes by A. Ogston, R. Geyer, P. Traykovski; suspended-sediment dynamics by P. Hill and T. Milligan; seabed thermal processes by J. Thomson and C. Chickadel.

PUBLICATIONS (Gulf of Lions)

Three primary papers

T.M. Drexler and C.A. Nittrouer, Stratigraphic signatures due to flood deposition near the Rhone River, Gulf of Lions, Northwest Mediterranean Sea, *Cont. Shelf Res., 28,* 1877-1894 (2008).

T.M. Drexler, A.S. Ogston, C.A. Nittrouer, B.L. Mullenbach, A.L. DeGeest, Sediment-transport mechanisms and depositional patterns at the southwest terminus of the mid-shelf mud deposit in the Gulf of Lions, *Mar. Geol.* (in review).

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Other publications

A. DeGeest, B.L. Mullenbach, P. Puig, C.A. Nittrouer, T.M Lomnicky, D.L. Orange, X. Durrieu de Madron, Sediment accumulation in the western Gulf of Lions, France: the role of Cap de Creus Canyon in linking shelf and slope sediment dispersal systems, *Cont. Shelf Res., 28,* 2031-2047 (2008).

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T. Drexler, C. Nittrouer, A. Ogston, P. Puig, B. Mullenbach, A. DeGeest, Sediment dispersal in the Gulf of Lions: The journey from the Rhone River through submarine canyons in the southwest gulf, AGU/ASLO Ocean Sciences Meeting, Honolulu (2006).

C. Nittrouer, T. Drexler, B. Mullenbach, J. Walsh, P. Puig, A. Ogston, J. Parsons, G. Kineke, S. Kuehl, The importance of modern submarine canyons as sediment conduits on tectonically active continental margins, AGU-ASLO Ocean Sciences Meeting, Honolulu (2006).

B.L. Mullenbach, P. Puig, A.L. DeGeest, D.L. Orange, C.A. Nittrouer, T.M. Drexler, Cap de Creus canyon: a link between shelf and slope sediment-dispersal systems in the Gulf of Lions, NW Mediterranean, AGU-ASLO Ocean Sciences Meeting, Honolulu (2006).